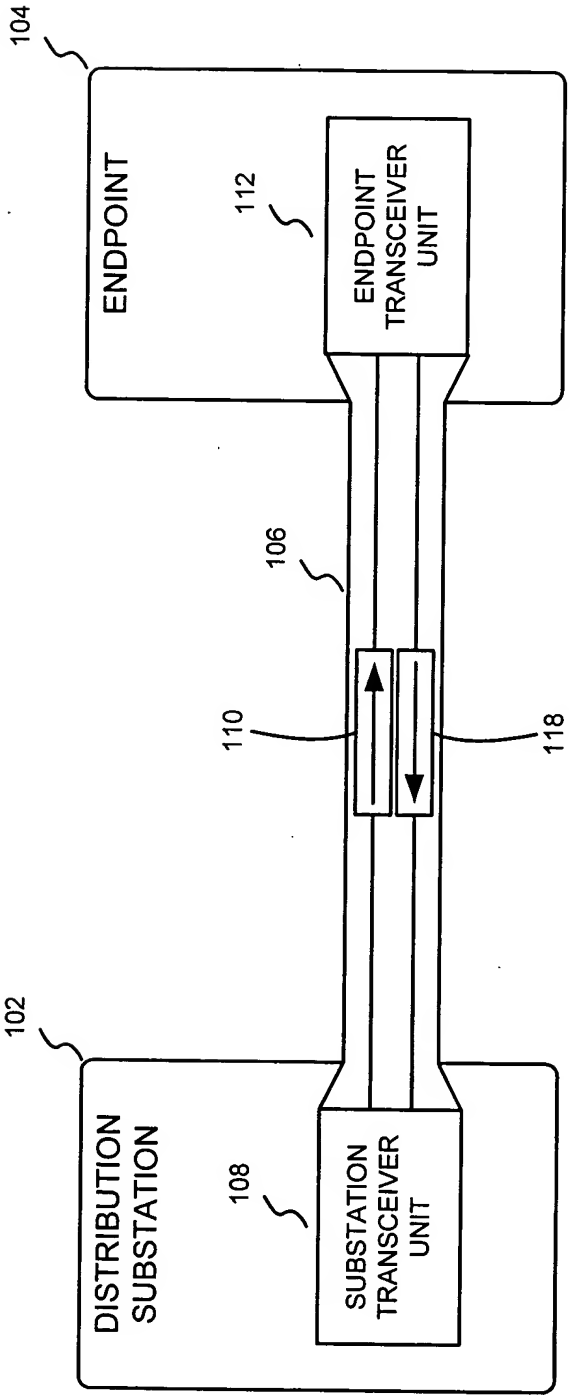
104
ENDPOINT
112
ENDPOINT TRANSCEIVER UNIT
106
110
118
102
DISTRIBUTION SUBSTATION
108
SUBSTATION TRANSCEIVER UNIT

FIGURE 1

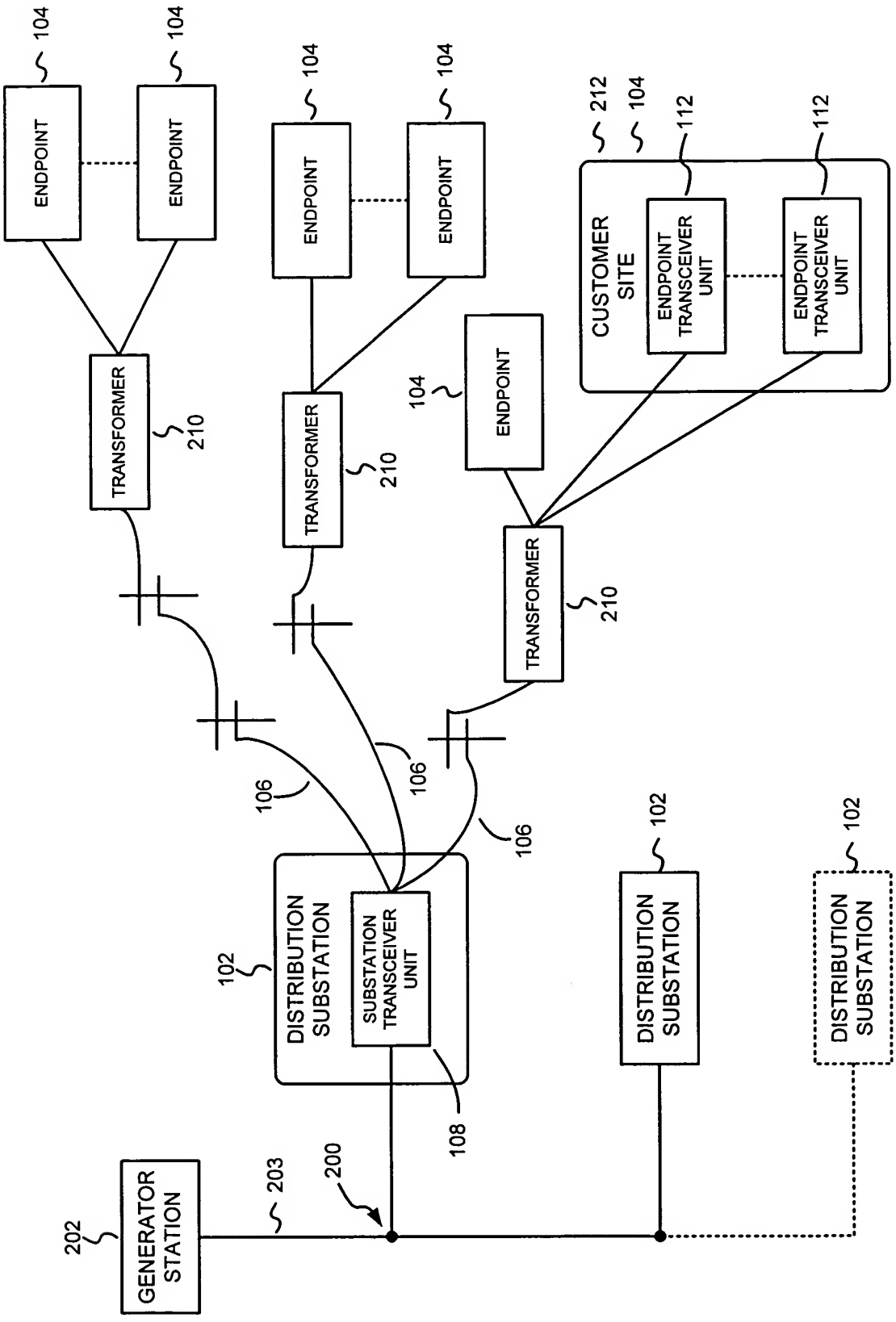
104
ENDPOINT
104
ENDPOINT
104
ENDPOINT
104
ENDPOINT
212
104
112
112
CUSTOMER SITE
ENDPOINT TRANSCEIVER UNIT
ENDPOINT TRANSCEIVER UNIT
104
ENDPOINT
TRANSFORMER
210
TRANSFORMER
210
TRANSFORMER
210
106
106
106
102
DISTRIBUTION SUBSTATION
SUBSTATION TRANSCEIVER UNIT
108
102
DISTRIBUTION SUBSTATION
102
DISTRIBUTION SUBSTATION
202
GENERATOR STATION
203
200

FIGURE 2

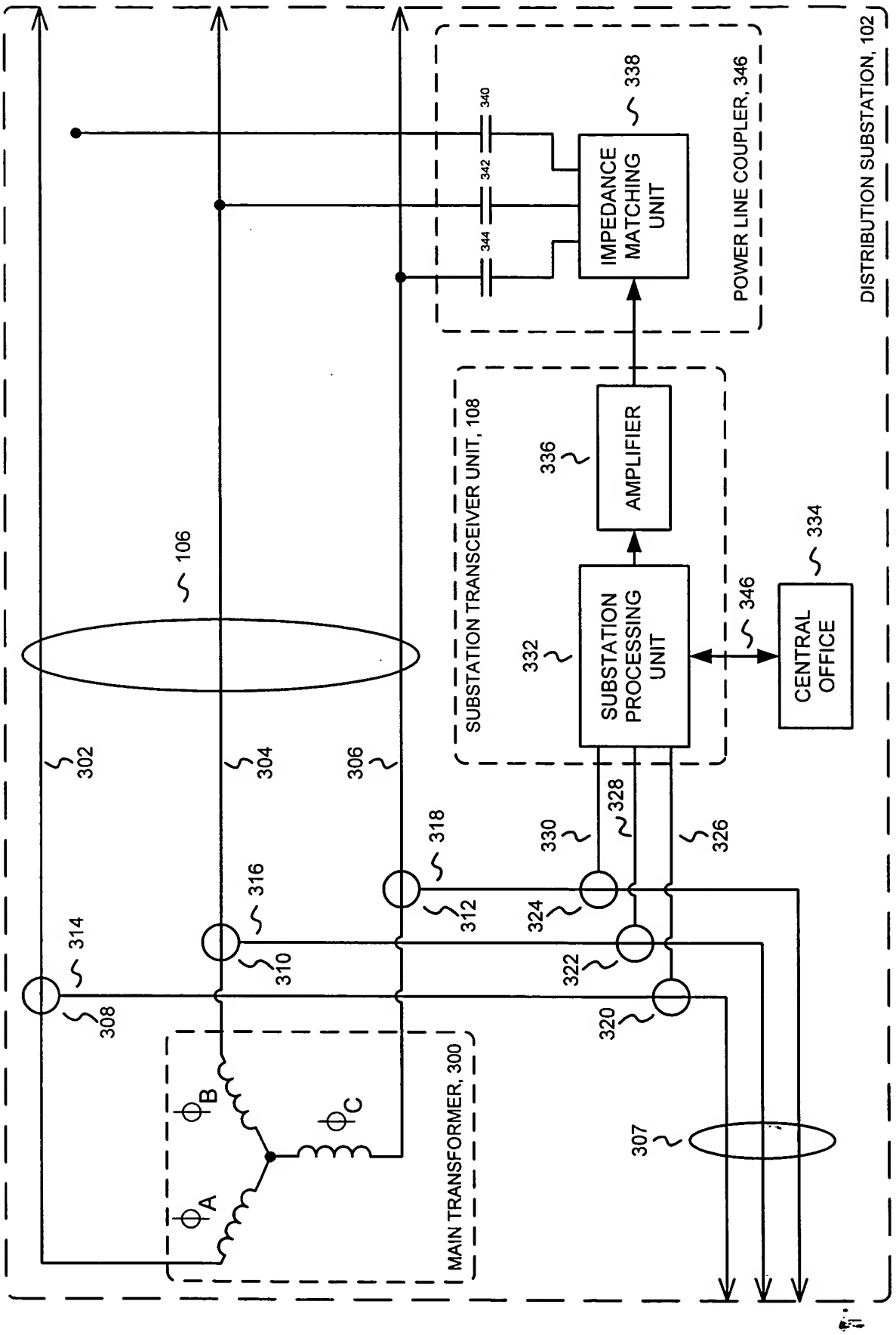
DISTRIBUTION SUBSTATION, 102
POWER LINE COUPLER, 346
IMPEDANCE MATCHING UNIT
338
340
342
344
SUBSTATION TRANSCEIVER UNIT, 108
AMPLIFIER
336
SUBSTATION PROCESSING UNIT
332
346
CENTRAL OFFICE
334
106
302
304
306
318
316
314
312
310
308
330
328
326
324
322
320
307
MAIN TRANSFORMER, 300
ϕ_A
ϕ_B
ϕ_C

FIGURE 3

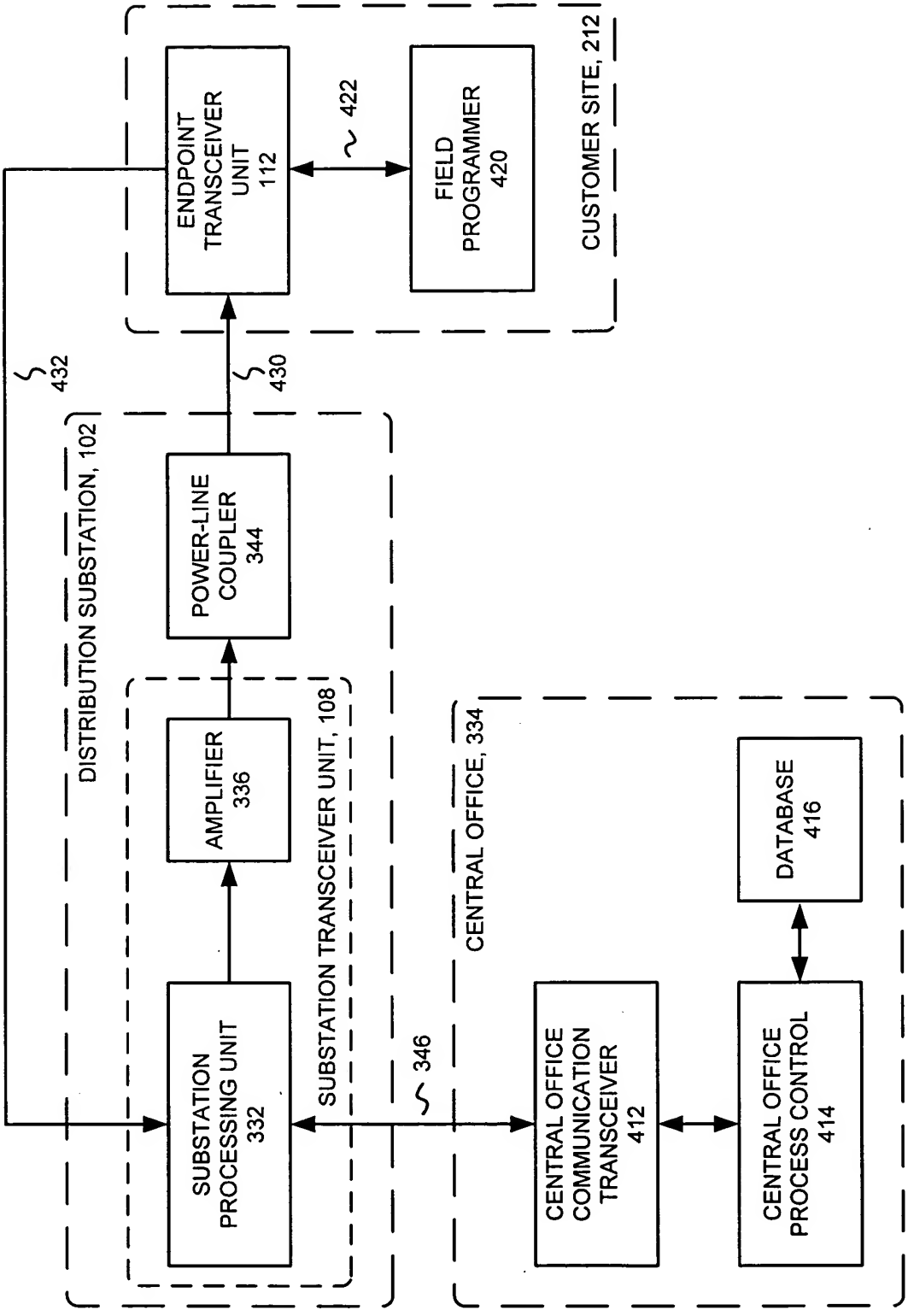
DISTRIBUTION SUBSTATION, 102
SUBSTATION TRANSCEIVER UNIT, 108
CENTRAL OFFICE, 334
CUSTOMER SITE, 212
SUBSTATION PROCESSING UNIT 332
AMPLIFIER 336
POWER-LINE COUPLER 344
ENDPOINT TRANSCEIVER UNIT 112
FIELD PROGRAMMER 420
CENTRAL OFFICE COMMUNICATION TRANSCEIVER 412
CENTRAL OFFICE PROCESS CONTROL 414
DATABASE 416
346
422
430
432

FIGURE 4

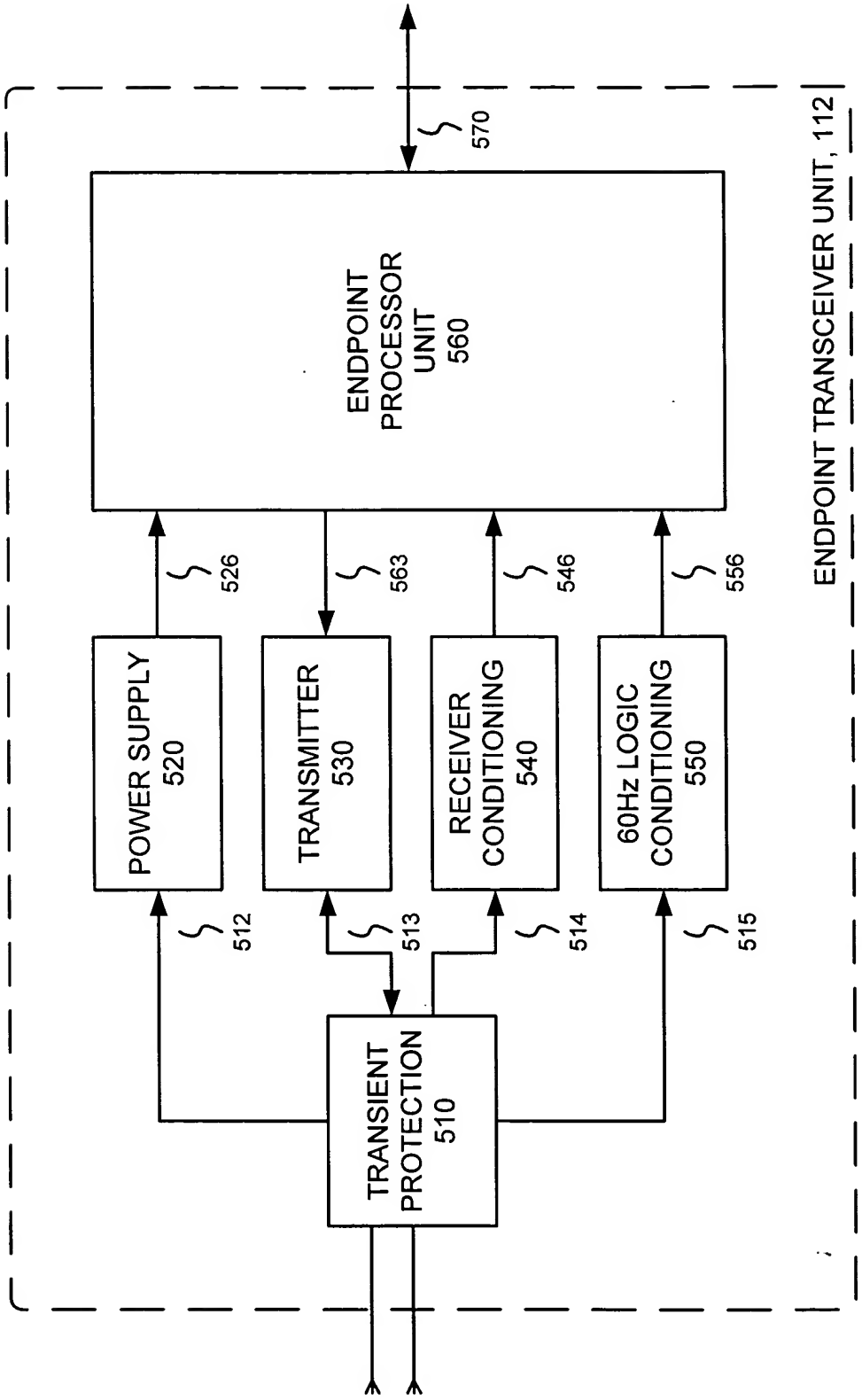
ENDPOINT TRANSCEIVER UNIT, 112
570
ENDPOINT PROCESSOR UNIT 560
526
563
546
556
POWER SUPPLY 520
TRANSMITTER 530
RECEIVER CONDITIONING 540
60Hz LOGIC CONDITIONING 550
512
513
514
515
TRANSIENT PROTECTION 510

FIGURE 5

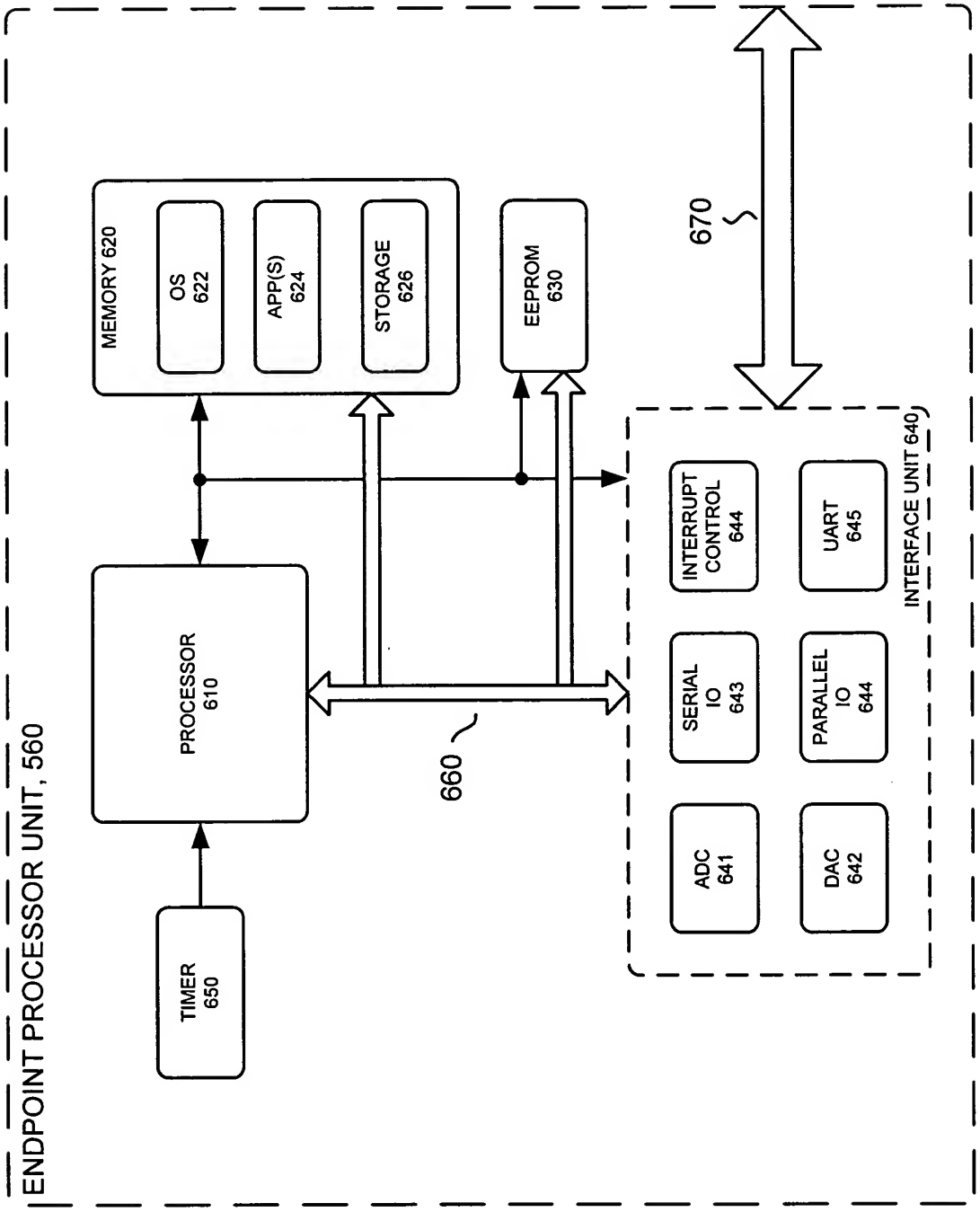
ENDPOINT PROCESSOR UNIT, 560
MEMORY 620
OS 622
APP(S) 624
STORAGE 626
EEPROM 630
670
PROCESSOR 610
660
TIMER 650
INTERFACE UNIT 640
INTERRUPT CONTROL 644
UART 645
SERIAL IO 643
PARALLEL IO 644
ADC 641
DAC 642

FIGURE 6

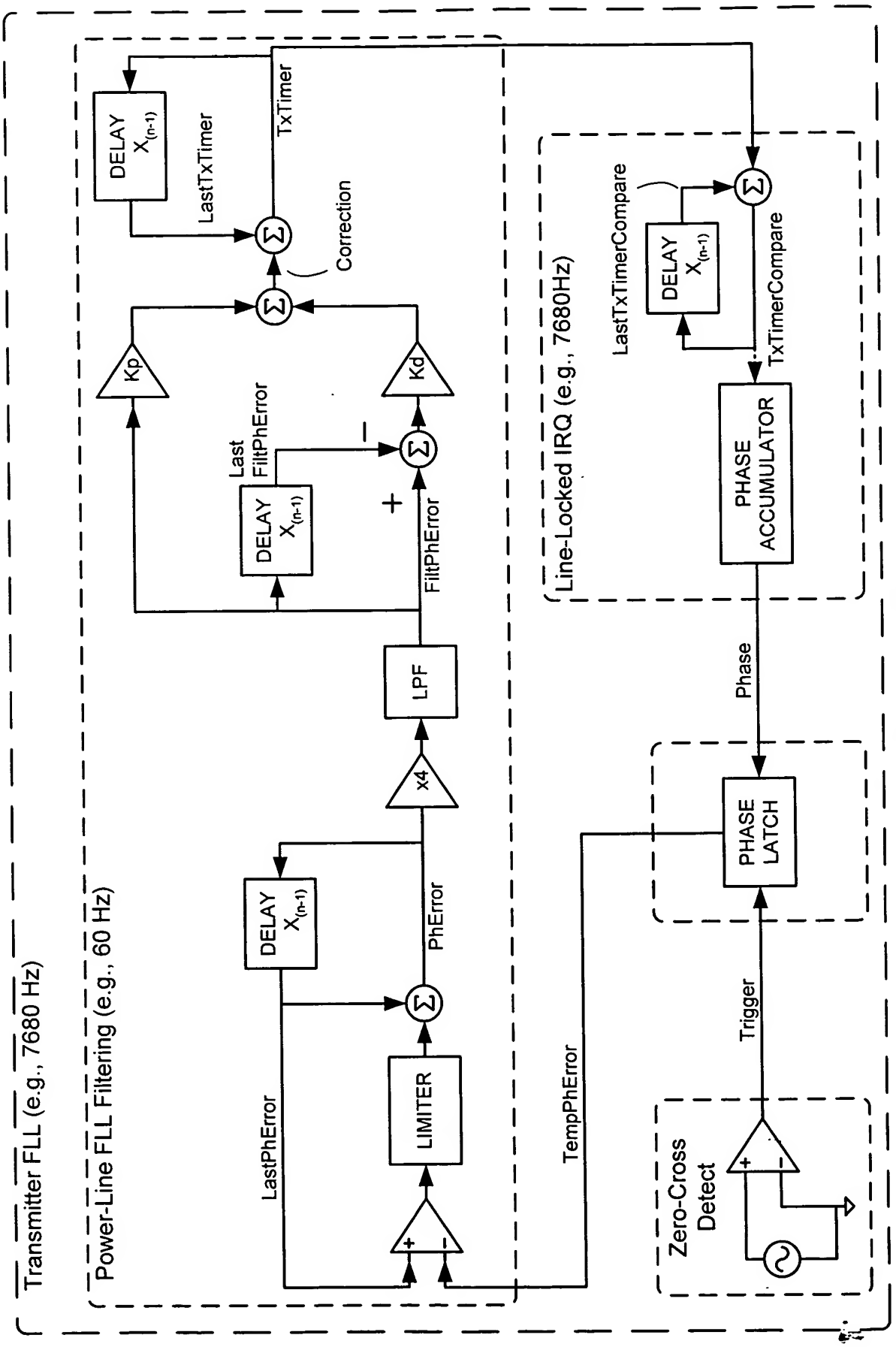
Transmitter FLL (e.g., 7680 Hz)
Power-Line FLL Filtering (e.g., 60 Hz)
Line-Locked IRQ (e.g., 7680Hz)
DELAY X(n-1)
LastTxTimer
TxTimer
Correction
Kp
Kd
Last FiltPhError
FiltPhError
LPF
x4
PhError
LIMITER
LastPhError
TempPhError
LastTxTimerCompare
TxTimerCompare
PHASE ACCUMULATOR
Phase
PHASE LATCH
Trigger
Zero-Cross Detect

FIGURE 7

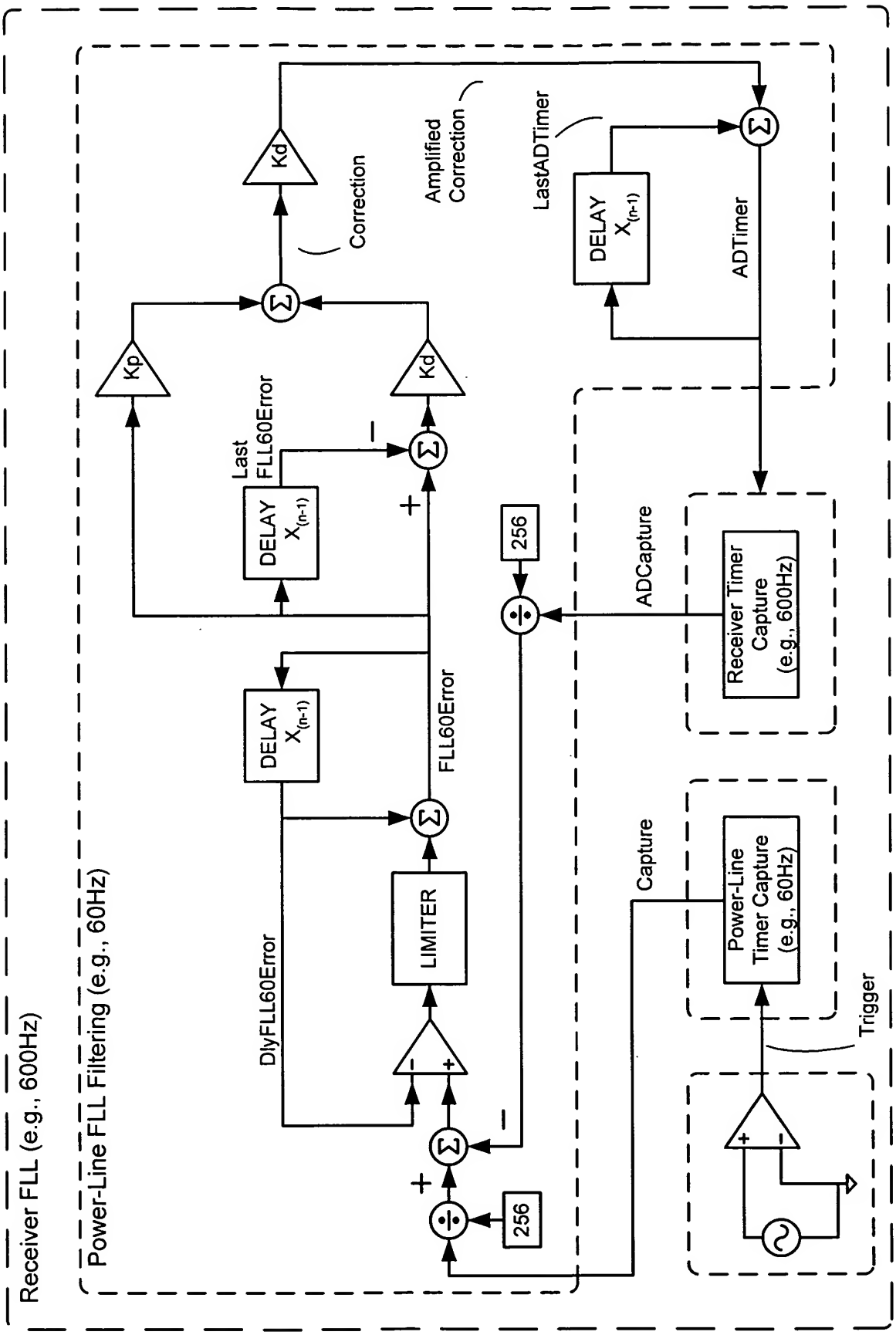
Receiver FLL (e.g., 600Hz)
Power-Line FLL Filtering (e.g., 60Hz)
Kd
Correction
Amplified Correction
LastADTimer
DELAY X(n-1)
ADTimer
Kp
Kd
Last FLL60Error
DELAY X(n-1)
256
ADCapture
Receiver Timer Capture (e.g., 600Hz)
DELAY X(n-1)
FLL60Error
LIMITER
DlyFLL60Error
Capture
Power-Line Timer Capture (e.g., 60Hz)
256
Trigger

FIGURE 8

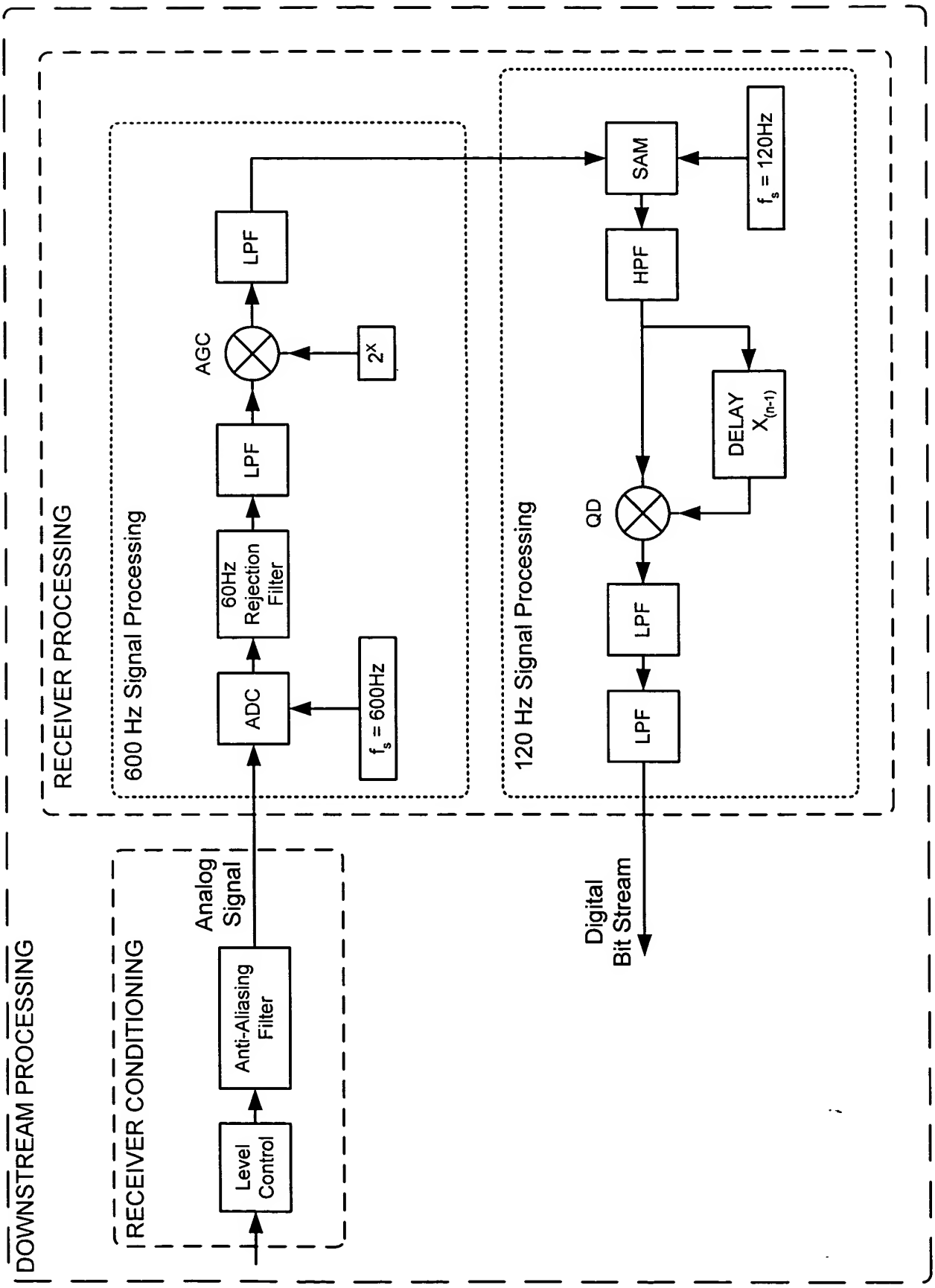
DOWNSTREAM PROCESSING
RECEIVER CONDITIONING
Level Control
Anti-Aliasing Filter
Analog Signal
RECEIVER PROCESSING
600 Hz Signal Processing
ADC
f_s = 600Hz
60Hz Rejection Filter
LPF
AGC
2^X
LPF
120 Hz Signal Processing
SAM
f_s = 120Hz
HPF
DELAY $X_{(n-1)}$
QD
LPF
LPF
Digital Bit Stream

FIGURE 9

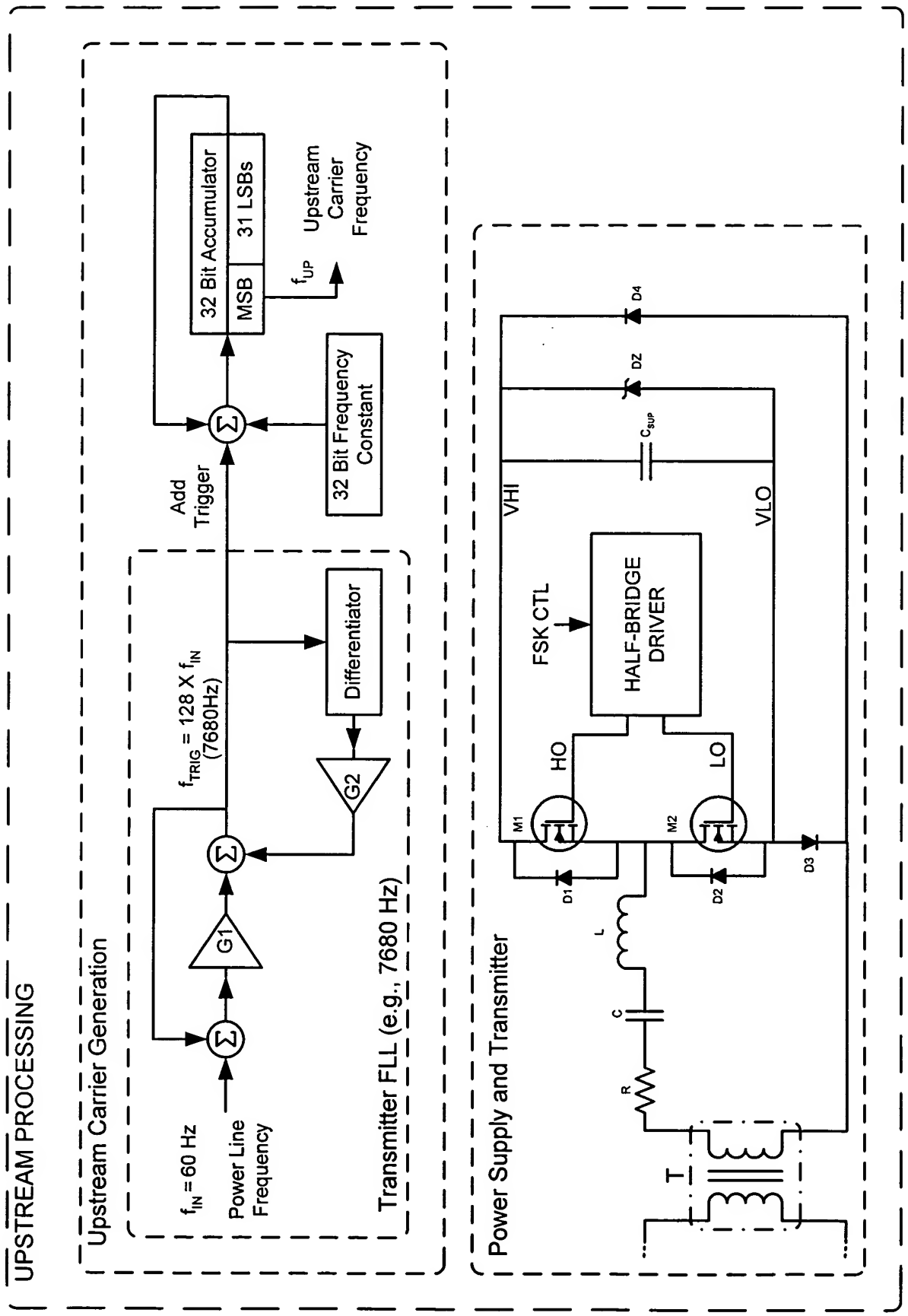
UPSTREAM PROCESSING
Upstream Carrier Generation
Transmitter FLL (e.g., 7680 Hz)
Power Supply and Transmitter
32 Bit Accumulator
MSB
31 LSBs
f_{UP}
Upstream Carrier Frequency
32 Bit Frequency Constant
Add Trigger
f_{TRIG} = 128 X f_{IN} (7680Hz)
Differentiator
G1
G2
f_{IN} = 60 Hz
Power Line Frequency
FSK CTL
HALF-BRIDGE DRIVER
HO
LO
VHI
VLO
C_{SUP}
D1
D2
D3
D4
M1
M2
L
C
R
T

FIGURE 10

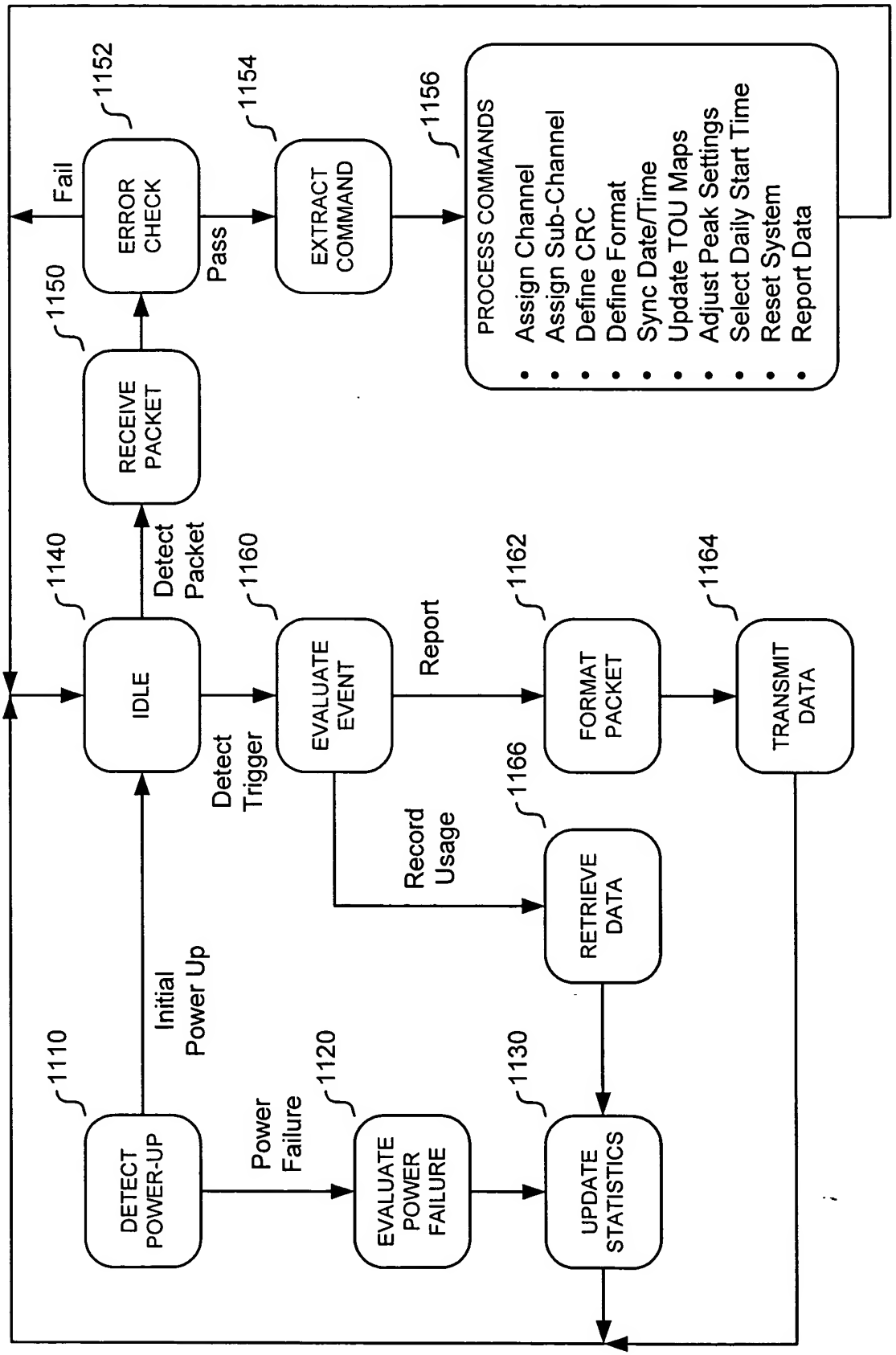
1110
DETECT POWER-UP
Initial Power Up
1120
Power Failure
EVALUATE POWER FAILURE
1130
UPDATE STATISTICS
1140
IDLE
Detect Packet
1150
RECEIVE PACKET
1152
ERROR CHECK
Fail
Pass
1154
EXTRACT COMMAND
1156
PROCESS COMMANDS
Assign Channel
Assign Sub-Channel
Define CRC
Define Format
Sync Date/Time
Update TOU Maps
Adjust Peak Settings
Select Daily Start Time
Reset System
Report Data
Detect Trigger
1160
EVALUATE EVENT
Report
1162
FORMAT PACKET
1164
TRANSMIT DATA
Record Usage
1166
RETRIEVE DATA

FIGURE 11

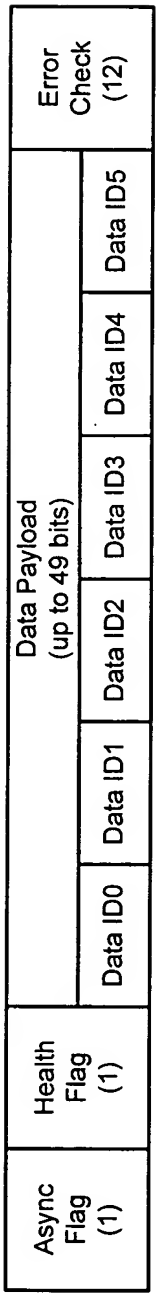
Async Flag (1)
Health Flag (1)
Data Payload (up to 49 bits)
Data ID0
Data ID1
Data ID2
Data ID3
Data ID4
Data ID5
Error Check (12)

FIGURE 12

DataID	Name	Description
0	Null	Empty Packet or ending packet
1	KWH1	Current power usage meter reading in units of kWH
2	TOU1	Null or the total number of kWH accumulated in the TOU1 bucket
3	TOU2	Null or the total number of kWH accumulated in the TOU2 bucket
4	TOU3	Null or the total number of kWH accumulated in the TOU3 bucket
5	TOU4	Null or the total number of kWH accumulated in the TOU4 bucket
6	Peak1	Total number of kWH used at the recorded peak time for TOU1 Map
7	Peak2	Total number of kWH used at the recorded peak time for TOU2 Map
8	Peak3	Total number of kWH used at the recorded peak time for TOU3 Map
9	Peak4	Total number of kWH used at the recorded peak time for TOU4 Map
10	Peak1Time	Time of peak demand for TOU1 Map
11	Peak2Time	Time of peak demand for TOU2 Map
12	Peak3Time	Time of peak demand for TOU3 Map
13	Peak4Time	Time of peak demand for TOU4 Map
14	Peak1Date	Date for Peak1 Demand
15	Peak2Date	Date for Peak2 Demand
16	Peak3Date	Date for Peak3 Demand
17	Peak4Date	Date for Peak4 Demand
18	LastPeak1	Last Peak1 Demand
19	LastPeak2	Last Peak2 Demand
20	LastPeak3	Last Peak3 Demand
21	LastPeak4	Last Peak4 Demand
22	LastPeak1Time	Time of Last Peak1 demand
23	LastPeak2Time	Time of Last Peak2 demand
24	LastPeak3Time	Time of Last Peak3 demand
25	LastPeak4Time	Time of Last Peak4 demand
26	LastPeak1Date	Date of Last Peak1 demand
27	LastPeak2Date	Date of Last Peak2 demand
28	LastPeak3Date	Date of Last Peak3 demand
29	LastPeak4Date	Date of Last Peak4 demand
30 - 41	----------	Reserved

TABLE 1

DataID	Name	Description
42	MomInt	Total number of momentary interruptions
43	MomEvent	Total number of momentary event interruptions
44	SusInt	Total number of sustained interruptions
45	SusIntDur	Total accumulated time for sustained interruptions
46	ConfigStatusFlags	Configuration status flags
47	SerNum	An internal serial number for the endpoint
48	ModelID	Identifies the model type or model family for the endpoint
49	HWRev	Hardware revision ID for the endpoint
50	SWVersion	Software version info for the endpoint
51	FlashCRC	CRC of application code
52	ReqID	Request ID of last async-type request received by the endpoint
53	LastResetTime	Time of last demand reset in minutes
54	LastResetDay	Day of the last demand reset in day-of-year format
55	Group 0	Group Address that the endpoint subscribes to for downstream reception
56	Group 1	Group Address that the endpoint subscribes to for downstream reception
57	Group 2	Group Address that the endpoint subscribes to for downstream reception
58	Group 3	Group Address that the endpoint subscribes to for downstream reception
59	Group 4	Group Address that the endpoint subscribes to for downstream reception
60	Group 5	Group Address that the endpoint subscribes to for downstream reception
61	Group 6	Group Address that the endpoint subscribes to for downstream reception
62	Group 7	Group Address that the endpoint subscribes to for downstream reception
63	PacketStartTime	Time of the day that the first bit of the upstream transmission starts
64	ElectricMetTime	The time at which electric metrology readings are captured - time in minutes
65	MomLogPtr	Memory address pointer for storing the next detected momentary interrupt
66	TxConst0	Transmitter upstream frequency constant for logic 0 modulation
67	TxConst1	Transmitter upstream frequency constant for logic 1 modulation
68	TxSubID	Sub-channel ID assigned for upstream communications
69 - 129	----------	Reserved
130	InternalBIT	Built in test flag for internal faults
131	InterfaceBIT	Built in test flag for interface faults
132	SystemStatus	Built in status flags

TABLE 2

DataID	Name	Description
133	Minutes	The current endpoint time in minutes (0 - 1439, 0 = Midnight)
134	DayOfWeek	The current endpoint day of the week (0 - 6, 0 = Sunday)
135	DayOfYear	The current endpoint day of the year (0-365, 0 = Jan 1)
136	TxBuffer	A variable length buffer that is internally used by the endpoint
137	SubIDCount	Number of SubIDs received by the endpoint since power-up
138	SequenceNum	The sequence number of the currently loaded packet
139	Temperature	The current internal temperature of the endpoint
140	SubID	Current sub-channel ID for the current downstream transmission
141	Demand	Instantaneous demand recorded by the endpoint over the last peak demand interval
142	WhiteFilter	Filtered maximum level for white while the disk is in the white state
143	BlackFilter	Filtered minimum level for black while the disk is in the black state
144	WhiteThreshold	Threshold above which the disk state is considered white
145	BlackThreshold	Threshold below which the disk state is considered black
146	OptoMin	Minimum reading for FilteredOpto
147	OpticMax	Maximum reading for FilteredOpto
148	FilteredOpto	Filtered optic reading that is used to determine the disk state
149	KhConst	32-bit constant
150	AGCLevel	8-bit AGC setting, where the gain of the front end is set to $2^{AGCLevel}$
151	MeterGroupCRC	The CRC of the Meter and Group configuration settings
152	BlackMin	Minimum reading while disk is in a black state - unfiltered
153	WhiteMax	Maximum reading while disk is in a white state - unfiltered
154	OptoSample	Unfiltered Optic reading
155	kWHAccumulator	32-bit partial kWH accumulator in units of $1/2^{24}$ of a kWH
156	Kp7680	8 Bit 7680 Hz FLL proportional error gain coefficient
157	Kd7680	8 Bit 7680 Hz FLL differential error gain coefficient
158	Kp60	8 Bit 60 Hz FLL proportional error gain coefficient
159	Kd60	8 Bit 60 Hz FLL differential error gain coefficient
160	Kc60	8 Bit 60 Hz FLL common gain coefficient
161	FLL7680UnLckCt	Unlocked counter for 7680 Hz FLL
162	FLL7680UnLckMax	Max since power-up of Unlocked counter for 7680 Hz FLL

TABLE 3

DataID	Name	Description
163	FLL60UnLckCt	Unlocked counter for 60 Hz FLL
164	FLL60UnLckMax	Max since power-up of Unlocked counter for 7680 Hz FLL
165 - 254	----------	Reserved
255	OnesFill	56-bit constant of all 1's for filling upstream packets when necessary

TABLE 4